REPORT RESUMES

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AN INVESTIGATION OF THE TRAINING AND SKILL REQUIREMENTS OF INDUSTRIAL MACHINERY MAINTENANCE WORKERS. VOLUME II. FINAL REPORT.

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MIDWEST INST. FOR EDUCATIONAL RES. AND TRAINING

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THE APPENDIXES FOR "AN INVESTIGATION OF THE TRAINING AND SKILL REQUIREMENTS OF INDUSTRIAL MACHINERY MAINTENANCE WORKERS, FINAL REPORT, VOLUME I" (VT 004 006) INCLUDE (1) TWO LETTERS FROM PLANT ENGINEERS STRESSING THE IMPORTANCE OF TRAINING MACHINERY MAINTENANCE WORKERS, (2) A DESCRIPTION OF THE MAINTENANCE TRAINING SURVEY, A SAMPLE QUESTIONNAIRE, AND LISTS OF KNOWLEDGES SUPERVISORS IN INDUSTRY FELT MECHANICAL REPAIRMEN SHOULD HAVE, (3) A LIST OF OCCUPATIONS IN WHICH THE BASIC MAINTENANCE SUBJECTS ARE APPLICABLE, (4) AN INVENTORY OF SYSTEMS AND COMPONENTS OF INDUSTRIAL MACHINERY, (5) SAMPLE WORK SCHEDULES FOR APPRENTICESHIP TRAINING, (6) DIAGRAMS SHOWING THE ALLOCATION OF SUBJECT TIME IN VARIOUS MAINTENANCE TRAINING PROGRAMS, (7) INFORMATION CONCERNING A PROPOSED CLEARINGHOUSE FOR INDUSTRIAL TRAINING MATERIALS, AND (8) A CORE CURRICULUM FOR A BASIC MAINTENANCE TRAINING PROGRAM. (HC)

IDWEST INSTITUTE *for* RESEARCH & TRAINING

FINAL REPORT

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AN INVESTIGATION OF THE TRAINING AND SKILL REQUIREMENTS OF INDUSTRIAL MACHINERY MAINTENANCE WORKERS

Volume II

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Volume II Contains the Appendices Referred to in Volume I. These Appendices Provide Supporting and Supplementary Data to the Text.

APPENDIX A

LETTERS OF THE PLANT ENGINEERS

An Open Letter to the Membership on Craft Training

From: Jim Beatty, Immediate Past President and Chairman, National Training Committee

As one of my last "President's Messages," I wrote in the June Newsletter of the conditions, as they appear to me, that concern the obtaining of young people for apprenticeship and other pre-craftsman training programs. Although I have received some comment from the membership concerning my editorial opinion, the overall reaction has been very slight.

To refresh your memories - and to inform those who may not have read the article - it seems that, in many areas, the qualifications of those young people who are interested in and available for pre-craft training are very inadequate. As a consequence, when replacements in craft groups are necessary, either expensive and time consuming screening procedures must be followed, or we are forced to accept unqualified people and subject them to extensive pre-training before we can truly begin their craft training.

In addition, the old pride in manual accomplishment that was the hallmark of all good craftsmen seems to be dying out and no amount of training will instill this spirit - if it is truly lacking.

The causes of these conditions are probably many and varied. Paramount among these, however, as I see the conditions, is the great emphasis that is being placed on positions for which college training is necessary and the stigma that is becoming more and more associated with manual employment and a lack of college education.

Although I must be the last person in the world to state that this emphasis is wrong and that young people should not be encouraged to attend college, if possible, I definitely feel that this encouragement is being carried too far and that the resultant attitudes and conditions are causing great wrongs - both to many fine and talented young people, who are unable, for one reason or another, to attend college and to American industry, who needs these young people for highly skilled jobs that do not involve the necessity of a college education.

In the past, the son of a competent machinist could think of nothing more honorable than to follow in his father's footsteps. Today, however, that son usually will consider this alternative only as a last resort. In the meantime, he takes those courses in his high school training which prepare him for college attendance and when the time arrives that he is faced with the reality that he cannot attend college, he is totally unprepared, or nearly so, to enter an apprenticeship program or a trade school to learn his father's craft.

In addition, if you do find a young man of today who has learned the pride of craft accomplishment and truly does want to learn to prepare himself for a trade, he is faced with deterrants fit to try the patience of Job. Granted, I have seen a number of fine vocational educational programs - and I am sure that there are a great many more that I have not seen or even heard of. However, most of these are in the larger cities and there are far more localities who have little or no vocational programs in secondary schools. In addition, in many areas, where vocational programs have been started and large sums of money have been spent in furnishing the facilities for vocational training, that have seen vocational schools or vocational training departments become the dumping ground for the problem students from other areas of the educational system.

Finally, and probably the most henious of all, a young man that truly desires to prepare himself to be an electrician or a boilermaker, and, therefore, enters a vocational program in his high school, often finds himself the subject of the scorn of the non-vocational faculty of his school and of those of his peers who are engaged in other educational programs. He is looked down on as not having the ambition to aspire to better things or as not having the intelligence or drive to secure a "better education." Is it any wonder that most of the good young people never get into vocational training or soon transfer to other courses before completing the program?

Now I am not stating that the conditions that I have described are completely universal and that no good vocational program exists. As I have said before, some do - but not enough! Some excellent young people are being sent out to industry to be trained for craft jobs - but not enough! Some young people recognize their inability to attend college and do the best that they can to prepare themselves for a place in the world - but not enough!

Far too many merely try to make up for their lack by saying, "I didn't have a chance." Far too many expect industry - and the government - to plant the seeds of training in the sterile fields of their minds and hope the flowers of skill will choke out the weeds of disallusionment and dissatisfaction. Far too many are "contented" to live on welfare, scream for their rights and contribute nothing.

But there must be a solution to all of this - I was taught that little or nothing is really insoluable. First, the purpose of the National Training Committee, in this respect at least, is to confirm these conditions in a manner that they may be presented to responsible parties for correction. This program is being initiated by an arrangement with a large mid-western University in which graduate students will receive grants for doing research on the subject. As soon as plans are finalized, details of the program will be announced.

In addition, the Committee is working with a non-profit corporation that is doing research on the subject for the Federal government. This part of the program, too, is in developmental stages and more will be announced as plans are finalized.

However, any work that can be done by the National Committee must necessarily be of a general nature. The real results can only be obtained by groups working on a local level - with local people. In my last article, I suggested that Chapters take this task as a Chapter program and asked for comments - one way or another. To date, I have heard from only two Chapters, both indicating agreement with the project and signifying the intent to proceed. I feel that the problem is of great enough import that many more Chapters should "get on the band wagon." Let me hear from you! Let's get the ball rolling NOW! Send your answers to:

James P. Beatty
Burger Brewing Company
Central Parkway & Liberty St.
Cincinnati, Ohio 45214

If you have any facts that dispute what I have been saying or if you have any examples of how any community is satisfactorily dealing with the problem, I am as interested in hearing them as I am in hearing that you agree with me and want to help out in the project. Just let me hear from you.

PRESIDENT'S MESSAGE

In discussing the problems of the Plant Engineering profession with members who attended the National Meeting, a problem that has been bothering me for quite some time was one that always seemed to come up in every discussion. That was the problem of securing qualified and experienced craftsmen for openings in the Maintenance Department. Whether the Plant Engineer was from Los Angeles or from Brooklyn, from Texas City or Chicago, this was a topic that he was sure to mention as one that was causing trouble.

Since the Annual Meeting, I have had the opportunity to attend several other meetings, in widely scattered areas, and the problem seems to go a little deeper than just the immediate employment of skilled craftsmen -- the fulfillment of our present needs. Rather, the more pressing problem seems to be that of finding young people who are qualified to be trained to become the skilled craftsmen of the future. One Plant Engineer from the east coast, an officer in the Institute, told me that after trying to find several experienced men to fill vacancies in his Maintenance Department, he decided to solve the problem by employing young men as apprentices and train them himself. However, although the Personnel Department of his company was able to find quite a number of applicants who evidenced interest in apprentice training, less than ten percent of these young men had the sort of background to qualify them to learn a skilled trade without an excessive amount of re-training.

Without enumerating all of the other examples of this condition that I have heard in recent weeks, let us say that it seems that Plant Engineers are apparently headed for an extreme shortage of skilled craft manpower--if something isn't done, and soon.

First of all, what is the cause of this condition? In my opinion, one of several causes is the present trend in secondary education to promote preparation for college. Now, I do not feel that this trend is completely wrong, but that it is being over-done. As we all know, statistics prove that the majority of high school entrants do not go to college. Therefore, in my opinion, a great disservice is being done, not only to those who, for one reason or another, will not enter college, but also to the American economy. By encouraging students, by various means, to enter college preparatory courses, many young people are being guided into effectively wasting at least four years of their lives. If they were encouraged to enter into training during their secondary school years that would directly prepare them for a vocation, they would be more capable of securing gainful employment for themselves and industry would not be forced to pay the bill for preparing them to learn those things that they must know in order to be properly trained as skilled craftsmen.

In addition, it seems to me that in many instances, secondary schools are sadly unprepared to offer adequate vocational training to those students who are interested in this type of education. Not only are the courses that are offered outmoded and lacking, but the facilities available for these courses are inadequate and antiquated. For this reason, many young students with a real interest in vocational craft training, prefer to remain in the college preparatory courses rather than spend time in useless and outmoded "shop" courses. Of course, there are many exceptions to this condition. Many cities have excellent vocational programs. Most of these, however, are in the larger cities and are able to serve only a portion of the interested and qualified students of that city. The remainder of the students in these cities, as well as the students in other cities and towns with inadequate programs, are forced to "make do" with what is available to them.

How can the Plant Engineer, a very vitally interested party to this condition, go about effecting some improvements? In my opinion, there are two courses of action that are necessary. First, on the National level, the Institute, as an organization, must take steps to bring the significance of this condition to the attention of those in a position to effect a change of educational emphasis. In addition, steps must be taken on the National level to pursue a program of promoting secondary school vocational training for craft group occupations which will aid in readjusting the balance between college preparatory courses and "shop" training. Finally, a National effort must be made to secure funds and equipment for the establishment of proper training facilities, as well as to upgrade the vocational course offerings in line with modern industrial technical needs. This can be done by a reallocation of present educational funds, by new allocations of funds into educational channels or by donations of funds or equipment from industry.

The second course of action that must be taken will have to be a local effort. Plant Engineers, as individuals, will have to take a more active part in local educational activities. Some of the doctors, lawyers and shop keepers, that presently make up the bulk of local Boards of Education, must be replaced by Plant Engineers. The college professors and other professional "thinkers," that are responsible for the present emphasis on college preparation must be made to understand that the present attitude is unrealistic and detrimental.

Local AIPE Chapters, separately or banded together for joint action, must take the correction of the vocational training conditions as an action project and exert pressure on school boards and other educational agencies to effect changes which will upgrade this area of secondary schooling. They must also take any and all action that they can to change the attitude of students entering secondary schooling concerning vocational education.

The problem is with us NOW, as well as in the future. We must begin our action NOW or it will be highly magnified in the future. This editorial is the first in a series of steps planned by the National to do our part. The efforts of the National, however, will be to no avail if coordinate local action is also not taken. I urge all members and Chapters to seriously consider the conditions and take those steps that are appropriate in your locality. Analyze the skilled manpower conditions in your area and determine for yourself whether or not the situation is as serious for you as it is for other Plant Engineers. If you find that the condition is as I have outlined, take action and then let the National know what you are doing. If we can show concerted activity on the local level, the actions on the National level will be just that more effective.

It seems to me that we have a job to do -- LET'S DO IT!

Source: AIPE NEWSLETTER/MAY, 1966

APPENDIX B

THE MAINTENANCE TRAINING SURVEY

A Description of the Survey
Sample Questionnaire
Measures of Effectiveness

A Description of the Survey

A DESCRIPTION OF THE FIELD SURVEYS ON MACHINERY MAINTENANCE TRAINING REQUIRED.

The findings in Chapter III were made on the basis of information obtained from two sources: (1) in-depth personal interviews with maintenance supervisors of over one-hundred firms in all types of industries and with plants of all sizes, and (2) 263 responses of maintenance supervisors and plant engineers to a mailed questionnaire. The personal interviews provided the opportunity to formulate the questionnaire which was mailed to more than fifteen-hundred persons. A discussion of the personal interviews is given below, followed by a discussion of the questionnaire.

First, the various systems constituting industrial machinery (mechanical, hydraulic, pneumatic, etc.) were broken down into a check list of their component parts. The check list was used in the interviews in determining those components most problematic to the machinery maintenance worker. Also formulated were fifteen questions concerning the problems involved in industrial maintenance, the skills required for their solution, and the sources of training available for acquiring these skills.

For the in-depth personal interviews, one hundred and fifty firms, providing a cross-section of industry and size, were selected from the Chicago area. The check list and questions were then tested by interviewing several of the selected companies. Because it was not yet known which level in the maintenance department would provide the most useful information, it was necessary to interview the maintenance foremen, plant supervisors, and personnel directors. Upon completion of the personal interviews at a firm, the check list was left with the plant supervisor to be answered and returned.

Upon completion of twenty interviews, the approach was reexamined. The check list was altered to obtain information about what skills are required of various maintenance personnel rather than about which machine parts are most problematic. Furthermore, the interview with the personnel director was eliminated from the procedure because a position description providing the information available at this level could generally be obtained. The revised check list and questionnaire were mailed to the twenty plant supervisors or foremen perviously interviewed with an explanation of the revision. Personal interviews with maintenance supervisors and, when possible, with maintenannce foremen were conducted at an additional eighty-five firms. The survey questionnaire was then formulated on the basis of the results of the personal interviews and the check list.

THE QUESTIONNAIRE ON MACHINERY MAINTENANCE TRAINING REQUIREMENTS

I. Questionnaire Format

The questionnaire consisted of two major parts.

The first part consisted of a list of 107 subjects currently being taught in industrial training programs to maintenance workers. These subjects are representative of subjects being taught under the headings of blueprint reading, mathematics, measurement, mechanics, electricity, pneumatics, hydraulics, electronics, and miscellaneous.

Recipients of the questionnaire were asked to "...check each item which you feel an accomplished maintenance worker should know to adequately maintain the machinery and production equipment in your plant."

Six specific maintenance classifications were considered in this survey. The following definitions of the classifications were provided in the questionnaire instructions:

- Mechanical Repairman - a maintenance worker primarily involved in mechanical servicing and repair of production machinery.
- Electrician - a maintenance worker primarily involved in the servicing and repair of motors, starters, limit switches, and other electrical components.
- Hydraulic Repairman - a maintenance worker specializing in the servicing and repair of hydraulic circuitry and components.

- Electronic Repairman - a maintenance worker specializing in the servicing and repair of electronic instruments and controls.

- Millwright - a person primarily involved in the erection and installation of production machinery and facilities.

The scope of this evaluation was limited to the area of machinery maintenance. Such classifications as instrument repairman, stationary engineer, custodial workers, electronic technicians, plumber, etc. were considered to be either not sufficiently within the scope of the machinery maintenance field or too specialized to warrant specific identification.

The second part of the questionnaire was concerned with obtaining additional information and opinions concerning the sources of maintenance workers, amount and type of training, future needs, and maintenance force data.

II. Sample Selection and Response

The group surveyed consisted of people in industry who were responsible for the supervision of all aspects of maintenance in all types of industries and in all sizes of plants. Where possible this group also included those responsible for making decisions concerning the initial employment of maintenance workers. This type of individual is generally the maintenance supervisor, foreman or plant engineer.

To obtain a sample cross-section by geography, size of plant, type of equipment, and type of industry, the questionnaire was mailed to about 1500 individuals. Through the cooperation of the American Institute of Plant Engineers, this sample represented 50% of the membership of the AIPE throughout the U.S.

Questionnaires from 263 individuals were received. The results are shown in percentage terms in a following section of this appendix.

Sample Questionnaire

MIDWEST INSTITUTE *for* RESEARCH & TRAINING

Dear Sir:

Our organization, the Midwest Institute for Research and Training, is currently conducting a research program supported in part by the U. S. Office of Education dealing with the training and skill requirements of industrial maintenance personnel. The objective of this investigation is to determine the extent to which training programs for machinery maintenance workers can be provided in vocational, adult, and/or apprenticeship training courses. We feel that this research study can be a major step toward providing adequately trained maintenance workers for industry and, as such, should be of particular personal interest to you and to your company.

One major facet of this investigation is the determination of exactly what training and skills a maintenance worker must possess in order to adequately perform his job. To obtain information on these requirements, we have contacted a number of plant engineers and maintenance supervisors in the Chicago area to obtain their comments. We are now expanding the scope of our inquiry to include plant engineers in various industries and areas of the country.

The American Institute of Plant Engineers has graciously agreed to help us with this undertaking by distributing the enclosed questionnaire to its members at the local chapter meetings. We ask that each of you directly involved with industrial maintenance work and maintenance personnel complete the questionnaire and return it to us in the envelope provided.

Thank you very much for your help in this matter.

Sincerely,

Frank Lynn

FL:jf

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INSTRUCTIONS

The first part of this questionnaire contains a list of various items which an accomplished maintenance worker might have to know in order to adequately do his job. We would like to have you check each item which you feel an accomplished maintenance worker should know to adequately maintain the machinery and production equipment in your plant. For example, if you feel that a mechanical repairman should be able to read mechanical schematic drawings but that an electrician does not need to have this capability, then check the "Blue Print Reading" category in the column under "Mechanical Repairman" but not in the column under "Electrician".

One suggestion that we might make is that you call in one of your top maintenance workers in each category and jointly complete this part of the questionnaire with him. Many of the plant engineers that we have interviewed personally have found this technique most helpful.

One point which we would like to clarify is the meaning of the various titles for maintenance personnel used here since there appears to be little consistency in these job titles throughout industry. For the purpose of this inquiry, we have used the following definitions:

- **Mechanical Repairman - a maintenance worker who is primarily involved in mechanical servicing and repair of production machinery.**
- **Electrician - a maintenance worker primarily involved in the servicing and repair of motors, starters, limit switches, and other electrical components.**
- **Hydraulic Repairman - a maintenance worker who specializes in the servicing and repair of hydraulic circuitry and components.**
- **Electronic Repairman - a maintenance worker who specializes in the servicing and repair of electronic instruments and controls.**
- **Millwright - a person primarily involved in the erection and installation of production machinery and facilities.**

We are not interested in custodial workers, stationery engineers, or others whose primary duties are not concerned with the maintenance of production machinery and equipment. If you do not have maintenance workers in any of the above job categories, it is not necessary to complete those portions of the questionnaire.

The second part of the questionnaire is concerned with some additional background information, comments, and opinions which would be of help to us in this research investigation. We would be very grateful if you would also complete this portion of the questionnaire.

Please return this questionnaire to us in the envelope provided.

Thank you!

INVENTORY OF INDUSTRIAL MAINTENANCE PERSONNEL
TRAINING AND SKILL REQUIREMENTS

KNOWLEDGE REQUIRED BY AN "ACCOMPLISHED" MAINTENANCE WORKER	MAINTENANCE PERSONNEL						
	Mechanical Repairman (1)	Electrician (2)	Hydraulic Repairman (3)	Electronic Repairman (4)	Welder (5)	Millwright (6)	
BLUE PRINT READING							
• Mechanical schematics							(6)
• Electrical schematics - simple							(7)
• Electrical schematics - complex							(8)
• Hydraulic schematics - simple							(9)
• Hydraulic schematics - complex							(10)
• Mechanical, electrical & hydraulic symbols							(11)
• Read scale drawing							(12)
• Make freehand sketches							(13)
• Make scale drawings							(14)
• Lettering							(15)
MATHEMATICS AND MEASUREMENT							
• Arithmetic (Add, subtract, multiply & divide)							(16)
• Fractions							(17)
• Ratios, proportions & taper/foot							(18)
• Metric system							(19)
• Algebraic symbols							(20)
• Solve simple equations							(21)
• Calculate areas of geometric figures							(22)
• Calculate angles (sine, cosine, & tangent)							(23)
• Logarithms							(24)
• Compute degrees, arcs & sectors of circles							(25)
• Calculate rpm.; peripheral speed							(26)
MECHANICS							
• Basic Principles - Levers							(27)
• Basic Principles - Pulleys & gears							(28)
• Basic Principles - Inclined planes							(29)
• Basic Principles - Cams & other mechanisms							(30)
• Measurement - Rule or scale							(31)
• Measurement - Vernier caliper							(32)
• Measurement - Protractor							(33)
• Measurement - Micrometer							(34)

INVENTORY OF INDUSTRIAL MAINTENANCE PERSONNEL
TRAINING AND SKILL REQUIREMENTS

KNOWLEDGE REQUIRED BY AN "ACCOMPLISHED" MAINTENANCE WORKER	MAINTENANCE PERSONNEL Mechanical Repairman (1)	Electrician (2)	Hydraulic Repairman (3)	Electronic Repairman (4)	Welder (5)	Millwright (6)	
MECHANICS (con't)							
• Measurement - Dial indicator							(35)
• Measurement - Ring or plug gage							(36)
• Measurement - Screw threads							(37)
• Components - Belts, pulleys & chains							(38)
• Components - Couplings & drive shafts							(39)
• Components - Ball & roller bearings							(40)
• Components - Sleeve (journal) bearings							(41)
• Components - Wear plates & ways							(42)
• Components - Gears, spur							(43)
• Components - Gears, bevel, worm, etc.							(44)
• Components - Clutches & brakes							(45)
• Components - Cams & followers							(46)
• Components - Complex mechanisms							(47)
• Troubleshooting - Principles							(48)
• Troubleshooting - Practical training							(49)
• Conveyors and other Material Handling Equipment							(50)
HYDRAULICS							
• Basic Principles - Force, pressure & torque							(51)
• Basic Principles - Hydraulic Circuitry							(52)
• Basic Principles - Theory of hydraulic flow							(53)
• Basic Principles - Hydraulic Fluids							(54)
• Components - Pumps (gear)							(55)
• Components - Pumps (piston & vane)							(56)
• Components - Tubing & fittings							(57)
• Components - Filters							(58)
• Components - Pressure gages							(59)
• Components - Valves (manually operated)							(60)
• Components - Valves (solenoid & pilot operated)							(61)
• Components - Relief valves							(62)
• Components - Cylinders							(63)
• Components - Accumulators							(64)
• Components - Intensifiers							(65)

INVENTORY OF INDUSTRIAL MAINTENANCE PERSONNEL
TRAINING AND SKILL REQUIREMENTS

KNOWLEDGE REQUIRED BY AN "ACCOMPLISHED" MAINTENANCE WORKER	MAINTENANCE PERSONNEL Mechanical Repairman (1)	Electrician (2)	Hydraulic Repairman (3)	Electronic Repairman (4)	Welder (5)	Millwright (6)	
HYDRAULICS (con't)							
• Components - Packings & seals							(66)
• Components - Heat exchangers							(67)
• Troubleshooting - Principles							(68)
• Troubleshooting - Practical training							(69)
							(80-1)
ELECTRICAL & ELECTRONICS							
• Basic Principles - A-C theory							(5)
• Basic Principles - D. C. theory							(6)
• Basic Principles - Circuitry (series, parallel)							(7)
• Basic Principles - Wiring fundamentals							(8)
• Basic Principles - Color coding							(9)
• Basic Principles - Electronic circuitry							(10)
• Measurement - Ammeter & Voltmeter							(11)
• Measurement - Wattmeter							(12)
• Measurement - Oscilloscopes							(13)
• Components - Batteries							(14)
• Components - Resistors & capacitors							(15)
• Components - Relays							(16)
• Components - Motors							(17)
• Components - Generators							(18)
• Components - Vacuum tubes - control							(19)
• Components - Vacuum tubes - power							(20)
• Components - Transformers							(21)
• Components - Limit Switches							(22)
• Components - Starters							(23)
• Components - Transistors							(24)
• Components - Silicon controlled rectifiers							(25)
• Components - Oscillators							(26)
• Components - Potentiometers							(27)
• Components - Synchros & servomechanism							(28)
• Components - Electric eyes							(29)
• Troubleshooting - Principles							(30)

INVENTORY OF INDUSTRIAL MAINTENANCE PERSONNEL
TRAINING AND SKILL REQUIREMENTS

KNOWLEDGE REQUIRED BY AN "ACCOMPLISHED" MAINTENANCE WORKER	MAINTENANCE PERSONNEL Mechanical Repairman (1)	Electrician (2)	Hydraulic Repairman (3)	Electronic Repairman (4)	Welder (5)	Millwright (6)	
ELECTRICAL & ELECTRONICS (con't)							
• Troubleshooting - Practical training							(31)
PNEUMATICS							
• Basic Principles - Circuit theory							(32)
• Basic Principles - Pressure & force							(33)
• Components - Cylinders							(34)
• Components - Valves (manual)							(35)
• Components - Valves (solenoid & pilot-operated)							(36)
• Components - Compressors							(37)
• Components - Lubricators & filters							(38)
• Components - Regulators & pressure gages							(39)
• Components - Mufflers							(40)
• Components - Motors & rotary actuators							(41)
• Components - Dryers & coolers							(42)
• Troubleshooting - Principles							(43)
• Troubleshooting - Practical training							(44)
MISCELLANEOUS							
• Lubrication - Theory & principles							(45)
• Lubrication - Lubricants (greases, oils, etc.)							(46)
• Welding - Arc							(47)
• Welding - Gas							(48)
• Welding - Electronic (spot, projection)							(49)
• Soldering & brazing							(50)
• Report writing							(51)
• Slide rule							(52)
• Pipefitting							(53)
• Safety - Mechanical							(54)
• Safety - Electrical							(55)
• Safety - Hydraulic							(56)
• Safety - Pneumatic							(57)
• Other (Please Specify)							(58)

Additional Information on Maintenance Training and Skill Requirements

A. What per cent of your maintenance workers do you obtain from each of the following sources?

	<10%	10-25%	25-50%	50%>	
1. Production Workers	______	______	______	______	(59)
2. Apprenticeship Training	______	______	______	______	(60)
3. Off-the-Street Hiring	______	______	______	______	(61)
4. Trade Schools	______	______	______	______	(62)
5. Other Sources	______	______	______	______	(63)

B. Does your company have a formal maintenance training program for maintenance workers?

1. ________Yes 2. ________No (64)

If so, is it an . . . . (65)

1. ________apprenticeship training program?

2. ________on-the-job training program?

C. Approximately what per cent of your present maintenance staff has had formal maintenance training? (66)

1. ________Less than 5%

2. ________5 - 10%

3. ________10 - 25%

4. ________25 - 50%

5. ________More than 50%

D. Do you feel that a mechanical repairman should be a qualified machinist? (67)

1. ________Yes 2. ________No

E. What areas of maintenance training do you feel will become increasingly important in the future?

1. _____ Mechanics (68)

2. _____ Hydraulics (69)

3. _____ Pneumatics (70)

4. _____ Electronics (71)

5. _____ Other (Please specify) ____________________ (72)

F. What is the approximate distribution of personnel in your maintenance force? (80-2)

________ Mechanical Repairmen

________ Electricians

________ Hydraulic Repairmen

________ Electronic Repairmen

________ Welders

________ Millwrights

G. We would be very grateful for an additional comment or observations which you might have concerning this problem of maintenance training.

If possible, we would also like to have the following information.

Company Name ____________________

Primary Product ____________________

Your Name and Title ____________________

Measures of Effectiveness

The following pages of this appendix display the tabulated results of the mailed questionnaire. The quantative evaluation of each subject is calculated for each category of maintenance personnel considered. The Measures of Effectiveness, in percentage terms, are given within parentheses following the subject titles.

Mechanical Repairman

Measures of Effectiveness of Subjects

MECHANICAL REPAIRMAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Blueprint Reading	Mech. schematics (97) Read scale drawings (89) Make sketches (80) Symbols (75)	Hyd. schematics-simple (68)			Elec. schematics-simple (39)
Mathematics	Arithmetic (98) Fractions (93) Ratios, proportions, and taper/foot (78) Calculate RPMs; peripheral speeds (76)			Simple equations (80) Metric system (44)	Calculate Geom. areas (37) Compute degrees, arcs and sectors (33 Calculate angles (28) Algebraic Symbols (
Measurements	Rule or scale (98) Micrometer (93) Dial indicator (92) Screw threads (90) Vernier caliper (88) Protractor (79) Ring or plug gauge (77)				

MECHANICAL REPAIRMAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Mechanics					
Basic Principles	Pulleys & gears (96) Troubleshooting principles (93) Practical training (93) Levers (92) Cams & other mechanisms (87) Inclined planes(73)				
Components	Ball & roller bearings (95) Belts, pulleys & chains (95) Clutches & brakes (95) Sleeve bearings (95) Coupling & drive shafts (94) Spur gears (92) Bevel, worm, etc. gears (90) Wear plates and ways (89) Cams & followers (87) Conveyors (81) Complex mechanisms (72)				

MECHANICAL REPAIRMAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Hydraulics Basic Principles		Force, pressure & torque (63)		Theory of hydraulic flow (41) Hyd. fluids (41)	
Components	Packing and seals (80) Gear pumps (78) Piston & vane pumps (75) Manually operated valves (72) Cylinders (71)	Practical training (67) Tubing & fittings (67) Filters (66) Trouble shooting principles (70) Pressure gages (68) Relief valves (68)	Solenoid & pilot operated valves (60) Heat exchangers (58) Accumulators (54)	Intensifiers (41)	
Electrical & Electronic Basic Principles					AC theory (37) DC theory (28)
Components					

MECHANICAL REPAIRMAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Pneumatics Basic Principles	Pressure and force (77) Circuit theory (76)				
Components	Compressors(85) Lubricators and filters (85) Regulators & pressure gauges (82) Cylinders (79) Manual valves (79) Practical training (78) Troubleshooting principles (78) Mufflers (71) Solenoid or pilot-operated valves (71)	Dryers & coolers (69) Motors & rotary actuators (66)			
Miscellaneous	Safety (97) Lubricants (93) Lubrication (92) Pipe-fitting (77)	Soldering & brazing (63)		Welding arc (43) Report writing (42)	Welding gas (40)

Hydraulic Repairman

Measures of Effectiveness of Subjects

HYDRAULIC REPAIRMAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Blueprint Reading	Hyd. schematics Simple (91) Complex (81) Mech., elec. & hyd. symbols (80) Read scale drawings (73) Make freehand sketches (71)	Mech. schematics (69)		Elec. schematics (42)	
Mathematics	Arithmetic (92) Fractions (88)			Ratios, proportions, & taper/foot (50) Solve simple equations (50)	Calculate rpm; peripheral speed (39) Metric system (29) Calculate geom. areas (28) Algebraic symbols (27)
Measurement	Rule of scale (90)		Dial indicator (58) Micrometer (56) Vernier caliper (52)	Screw threads (47) Protractor (43) Ring or plug gauge (42)	

HYDRAULIC REPAIRMAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Mechanics					
Basic Principles	Troubleshooting-principles (79) Practical training (72)	Levers (63)	Pulley & gears (56) Cams & other mechanisms (56)		Inclined planes (39)
Components				Ball & roller bearings (50) Couplings & drive shafts(48) Belts, pulleys & chains (47) Clutches & brakes (43)	Sleeve bearings (40) Cams & followers (37) Spur gears (33) Complex mechanisms (32) Bevel, worm, etc. gears (30) Conveyors (27)
Hydraulics					
Basic Principles	Hyd. circuitry (96) Force, pressure & torque (93) Troubleshooting--Practical training (93) Principles (92)				

HYDRAULIC REPAIRMAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Hydraulics					
Basic Principles (continued)	Th. of hyd. flow (89)				
	Hyd. fluids (89)				
Components	Manually-operated valves (93)				
	Tubing & fittings (92)				
	Relief valves (92)				
	Cylinders (92)				
	Filters (91)				
	Pressure gauges (91)				
	Solenoid & pilot-operated valves (91)				
	Packing & seals(90)				
	Accumulators (88)				
	Gear pumps (87)				
	Intensifiers (82)				
	Piston & vane pumps (81)				
	Heat exchangers (77)				

HYDRAULIC REPAIRMAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Electrical & Electronic					
Basic Principles					
Components					AC theory (31)
Pneumatics					
Basic Principles	Pressure & force (79) Circuit theory (78) Troubleshooting--Principles (71)	Troubleshooting--Practical training (69)			
Components	Lubricators & filters (74) Regulators & pressure gauges (73) Manual valves (72) Solenoid & pilot operated valves(72)	Cylinders (70) Motors and rotary actuators (61)	Mufflers (59) Compressors (57) Dryers & coolers (53)		

HYDRAULIC REPAIRMAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Miscellaneous	Safety-- Hydraulic (97) Pneumatic (88) Mechanical (78) Pipefitting (71) Lubrication-- Theory & principles (71)	Safety-- Electrical (68) Lubrication-- Lubricants (61)		Report writing (44)	Soldering & brazing (38)

Electrician

Measures of Effectiveness of Subjects

ELECTRICIAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Blueprint Reading	Electrical schematics - Simple (93) Complex (76) Symbols (75)	Make sketches (68) Read scale drawings (68)		Mechanical schematics (41)	Hydraulic schematics Simple (32)
Mathematics	Arithmetic (94) Fractions (88)		Solve simple equations (55)		Calculate rpm; peripheral speed (40) Algebraic symbols (36 Ratios, proportions, taper/foot (35)
Measurement	Ammeter and Voltmeter (99) Wattmeter (94) Rule or scale (84)			Oscilloscopes (41)	Dial indicator (29) Micrometer (29) Protractor (27) Vernier caliper (27)
Mechanics Basic Principles		Troubleshooting Principles (67) Practical training (63)		Ball & roller bearings (45)	Levers (30) Pulleys & gears (30)
Components					Conveyors (35) Clutches & brakes (33) Sleeve bearings (33) Belts, pulley & chain (33) Couplings & drive

ELECTRICIAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Hydraulics					
Basic Principles					
Components		Solenoid & pilot-operated valves (62)			Troubleshooting Principles (26)
Electrical and Electronics					
Basic Principles	A-C theory (99) Circuitry(series parallel) (99) Wiring fundamentals (97) Color coding (96) D-C theory (94) Electronic circuitry (74)	Potentiometers (68)	Silicon-controlled rectifiers (60) Vacuum tubes power (56) Vacuum tubes control (53) Transistors (51)	Synchros & Servos (50)	Oscillators (37)
Components	Generators (99) Motors (99) Limit switches (98) Relays (97) Starters (96) Transformers (96) Troubleshooting Principles (94) Batteries (93) Resistors and capacitors (83)				

ELECTRICIAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Components (continued)	Electric eyes (77) Practical training (75)				
Pneumatics					
Basic Principles					
Components			Solenoid & pilot-operated valves (58)		Basic principles - circuit theory (34) Motors & rotary actuators (33) Troubleshooting principles (28)
Miscellaneous	Safety (95)		Lubrication (54)	Soldering and brazing (45) Report writing (41)	Lubricants (38)

Electronic Repairman

Measures of Effectiveness of Subjects

ELECTRONIC REPAIRMAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Blueprint Reading	Electrical schematics Simple (82) Complex (79)	Symbols (66) Make freehand sketches (64) Read drawings (62)			Mech. schematics (39 Hyd. schematics simple (27)
Mathematics	Arithmetic (94) Fractions (87)	Solve simple equations (61)		Algebraic symbols (48) Ratios, proportions & taper/foot (44)	Calculate RPM and speed (28) Metric system (27) Calculate angles (26)
Measurement	Ammeter & voltmeter (94) Oscilloscope (92) Watt meter (88) Rule or scale (82)				Micrometer (31) Protractor (29) Dial indicator (27) Vernier caliper (26)
Mechanics Basic Principles		Troubleshooting Principles (64)	Troubleshooting Practical training (56)		Levers (28) Pulleys & gears (28)
Components					

ELECTRONIC REPAIRMAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Hydraulics					
Basic Principles					
Components				Solenoid valves (38)	
Electrical & Electronics					
Basic Principles	Electronic circuitry (95) AC theory (94) DC theory (93) Circuitry (series, parallel) (93) Color coding (91) Wiring Fundamentals (91)				
Components	Resistors & capacitors (95) Transistors (95) Troubleshooting principles (95) Vacuum tubes (power) (95) Vacuum tubes (control) (94) Potentiometers (93) Relays (93) Silicon controlled rectifiers (91)	Motors (70) Starters (69) Generators (67)			

ELECTRONIC REPAIRMAN

	71-100%	61-70%	51-60%	41-50%	26-40%
Components (Continued)	Oscillators (90) Electric Eyes (89) Transformer (87) Batteries (86) Synchros and Servo-Mechanisms (86) Limit Switches (83) Troubleshooting Practical training (78)				
Pneumatics					
Basic Principles					Circuit Theory (31)
Components					Solenoid and Pilot-Operated Valves (28)
Miscellaneous	Safety-electrical (86)			Report writing (50)	Soldering and brazing (36) Lubrication (33) Slide Rule (31)

Welder

Measures of Effectiveness of Subjects

WELDER

	71-100%	61-70%	51-60%	41-50%	26-40%
Blueprint Reading	Reading scale drawings (83)		Make sketches (60) Mech. schematics (58)		Symbols (28)
Mathematics	Arithmetic (91) Fractions (86)				Ratios and proportions (39) Solve simple equations (30) Calculate Geom. areas (29) Compute degrees, arc and sectors (26)
Measurement	Rule or scale (89)		Protractor (55)		Vernier caliper (38) Micrometer (29)
Mechanics					
Basic Principles				Levers (41)	Pulleys & Gears (26) Inclined Planes (26)
Components					

WELDER

	71-100%	61-70%	51-60%	41-50%	26-40%
Hydraulics					
Basic Principles					
Components					
Electrical & Electronic					
Basic Principles					
Components					
Pneumatics					
Basic Principles					
Components					
Miscellaneous	Arc (97) Gas (97) Electronic (77) Soldering and brazing (92) Safety (80)				Report Writing (28) Pipe-fitting (27)

MILLWRIGHT

	71-100%	61-70%	51-60%	41-50%	26-40%
Blueprint Reading	Read scale drawings (92) Mech. schematics (82) Make sketches (74)			Symbols (48)	Hyd. schematics - simple (37)
Mathematics	Arithmetic (95) Fractions (91)	Ratios, proportions & taper/foot (69)	Calculate rpms; peripheral speeds (52)	Calculate geometrical areas (41)	Solve simple equations (39) Metric system (36) Compute degrees, arcs & sectors (34) Calculate angles (31)
Measurement	Rule or scale (96) Vernier caliper (71)	Protractor (69) Micrometer (69) Screw thread (69) Dial indicator (67)		Ring's Plug Gage (47)	
Mechanics Basic Principles	Levers (88) Pulleys & gears (87) Inclined planes (78)	Cams & other mechanisms (64)			

Millwright

Measures of Effectiveness of Subjects

MILLWRIGHT

	71-100%	61-70%	51-60%	41-50%	26-40%
Mechanics Components	Ball & roller bearings (81) Conveyors & other materials handling equipment (81) Couplings & drive shafts (81) Belts, pulleys & chains (80) Sleeve bearings (80) Clutches & brakes (74)	Wear plates & ways (70) Spur gears (68) Bevel, worm, etc., gears (66)	Troubleshooting Principles (59) Practical training (58) Cams & followers (58)		Complex mechanisms (38)
Hydraulics Basic Principles				Force, pressure and torque (46)	Hydraulic circuitry (26
Components				Packing & seals (46) Tubing and fittings (42) Manually-operated valves (41)	Gear Pumps (38) Pressure Gages (36) Cylinders (35) Piston & Vane Pumps (35) Relief Valves (34) Heat Exchangers (33) Troubleshooting Practical Training (33) Principles (31) Filters (30) Solenoid & pilot-operat valves (29)

MILLWRIGHT

	71-100%	61-70%	51-60%	41-50%	26-40%
Electrical and Electronics					
Basic Principles					
Components					
Pneumatics					
Basic Principles					Circuit theory (40) Pressure & force (39)
Components				Compressors (42) Lubricators & Filters (42)	Pressure regulators and Gages (38) Manual valves (36) Cylinders (34) Troubleshooting Principles (34) Dryers & cooler (33) Mufflers (31) Troubleshooting Practical training (31) Motors & rotary actuators (29) Solenoid & pilot-operate valves (29)
Miscellaneous	Safety (91) Lubrication (76) Lubricants (71)	Pipefitting (67)		Welding Arc (46) Gas (41) Soldering &	Report writing (35)

APPENDIX C

OCCUPATIONS IN WHICH THE BASIC MAINTENANCE SUBJECTS ARE APPLICABLE

OCCUPATIONS IN WHICH THE BASIC MAINTENANCE TRAINING SUBJECTS ARE APPLICABLE

OCCUPATIONAL TITLE	ESTIMATED NUMBER OF WORKERS
Air Conditioning; Refrigeration Mechanics	**0,000**
Airplane Mechanics	**4,000**
All-Round Machinists	*** See Below**
Appliance Servicemen	**10,000**
Automatic Bowling Machine Mechanics	**8,000**
Automobile Body Repairmen	**90,000**
Automobile Mechanics	**500,000**
Blacksmiths	**20,000**
Boilermaking Occupations	**21,000**
Bricklayers	**150,000**
Business Machine Servicemen	**70,000**
Carpenters	**800,000**
Diesel Mechanics	**----**
Electricians (Construction)	**150,000**
Elevator Constructors	**13,000**
Industrial Machine Repairmen	**150,000**
Inspectors (Manufacturing)	**400,000**
Instrument Makers (Mechanical)	*** See Below**
Instrument Repairmen	**75,000**
Layout Men	*** See Below**
Machine Tool Operators	**500,000**
Maintenance Electricians	**220,000**
Millwrights	**70,000**
Patternmakers (Foundry)	**19,000**
Plumbers; Pipefitters	**335,000**
Setup Men (Machine Tools)	**40,000**
Sheet-Metal Workers	**50,000**
Shop Trades (Railroad)	**98,800**
Stationary Engineers	**260,000**
Telephone Central Office Craftsmen	**65,000**
Telephone Central Office Equipment Installers	**18,000**

OCCUPATIONAL TITLE	ESTIMATED NUMBER OF WORKERS
Telephone Linemen & Cable Splicers	35,000
Telephone & PBX Installers and Repairmen	76,000
Television & Radio Service Technicians	115,000
Tool & Die Makers	140,000
Truck Mechanics & Bus Mechanics	105,000
Vending Machine Mechanics	15,000

*370,000 Machinists, Layout Men, and Instrument Makers were employed in early 1965.

Source: U. S. Department of Labor, Occupational Outlook Handbook, Bulletin No. 1450, U. S. Government Printing Office, Washington, D. C., 1966.

APPENDIX D

INVENTORY OF INDUSTRIAL MACHINERY COMPONENTS

INVENTORY OF SYSTEMS AND COMPONENTS OF PRODUCTION MACHINERY

MACHINERY SYSTEMS AND ENVIRONMENTAL FACTORS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	<
SYSTEMS								
Mechanical	X							
Hydraulic			X					
Pneumatic			X					
Electrical	X							
Cutting fluid							X	
Coolant			X					
Lubrication	X							
ENVIRONMENTAL FACTORS								
Explosive atmosphere								X
Corrosive gas, liquid								X
Abrasive atmosphere								X
Elevated temperatures						X		
Sanitation							X	

INVENTORY OF SYSTEMS AND COMPONENTS OF PRODUCTION MACHINERY

MACHINERY SYSTEMS AND COMPONENTS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	< 5
MECHANICAL SYSTEMS								
Main Power System								
External							X	
Belt or chain pickoff								X
Electric	X							
Hydraulic					X			
Pneumatic					X			
Internal combustion								X
Controls								
Automatic & semi		X						
Manual		X						
Belts, Chains & Pulleys								
Flat belts						X		
V-belts		X						
Timing belts						X		
Other belts							X	
Roller chains			X					
Silent chains								X
Block chains								X
Other chains						X		
Pulleys			X					
Sheaves - fixed		X						
Sheaves - adjustable								X
Sprockets			X					
Shafts & Couplings								
Shafts (rigid)	X							
Shafts (flexible)								X
Shear pins/ roll pins	X							
Keys	X							
Rigid couplings			X					
Flexible couplings						X		
Universal joint coupling							X	
Unknown couplings						X		

INVENTORY OF SYSTEMS AND COMPONENTS OF PRODUCTION MACHINERY

Mechanical Systems - Continued

MACHINERY SYSTEMS AND COMPONENTS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	< 5
Bearings								
Cylindrical roller			X					
Tapered roller				X				
Other roller						X		
Sleeve, journal		X						
Ball		X						
Ways			X					
Wear plates					X			
Other, unknown type		X						
Sealed			X					
Self lubricating							X	
Gears								
Spur		X						
Bevel, miter			X					
Helical; herringbone					X			
Worm			X					
Planetary								X
Rack & pinion			X					
Anti-backlash								X
Other, unknown					X			
Non-metallic								X
Gear train			X					
Speed reducer			X					
Mechanisms								
Intermittent gearing							X	
Escapements								X
Ratchets, pawls					X			
Clutches								
Square, jaw							X	
Spiral, jaw								X
Disk, friction					X			
Cone, friction								X
Rim, friction								X

INVENTORY OF SYSTEMS AND COMPONENTS OF PRODUCTION MACHINERY

Mechanical Systems - Continued

MACHINERY SYSTEMS AND COMPONENTS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	< 5
Clutches (Continued)								
Other friction unknown								X
Overload								X
Other, unknown					X			
Brakes								
Disk							X	
Drum							X	
Cone								X
Band						X		
Other, unknown						X		
Cams								
Disk edge			X					
Cylindrical							X	
Other, unknown			X					
Cam Followers								
Flat face (slider)					X			
Roller			X					
Miscellany								
Cranks			X					
Crankshafts				X				
Rocker arms				X				
Levers	X							
Springs	X							
Counter						X		
Shims		X						
Vernier scale						X		
Treadle				X				
Fans						X		
Shock mounts						X		
Leveling screws					X			
Eye bolt			X					
Yoke			X					
Magazine							X	

INVENTORY OF SYSTEMS AND COMPONENTS OF PRODUCTION MACHINERY

Mechanical Systems - Continued

MACHINERY SYSTEMS AND COMPONENTS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	< 5
Miscellany (Continued)								
Hopper					X			
Chute						X		
Flywheel						X		
Governor								X

INVENTORY OF SYSTEMS AND COMPONENTS OF PRODUCTION MACHINERY

MACHINERY SYSTEMS AND COMPONENTS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	< 5
HYDRAULIC SYSTEMS								
Operating Pressure								
Unknown					X			
0 - 99 psi							X	
100 - 4999 psi					X			
5000 psi and up								X
Pumps								
Gear								X
Piston				X				
Vane						X		
Screw								X
Unknown type					X			
Accumulator								
Bladder								X
Piston								X
Other, unknown								X
Intensifier								
Air-to-oil								X
Oil-to-oil								X
Unknown type								X
Fluid								
Oil			X					
Fire-resistant							X	
Conductors								
Hose			X					
Pipe			X					
Tubing				X				
Manifold				X				
Motors								
Gear								X
Piston							X	
Vane								X
Screw								X

INVENTORY OF SYSTEMS AND
COMPONENTS OF PRODUCTION MACHINERY

Hydraulic Systems - Continued

MACHINERY SYSTEMS AND COMPONENTS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	< 5
Motors (Continued)								
Unknown type								X
Rotary Actuators								
Vane								X
Internal helix								X
Rack & pinion								X
Other, unknown								X
Cylinders								
Single-acting						X		
Double-acting						X		
Telescoping								X
Unknown type							X	
Directional Flow Control Valves								
On-off only								
Check			X					
Gate, globe, ball, poppet, etc.				X				
Network switching (2 way, 3 way, 4 way)					X			
Volume Flow Control Valves								
Needle, restrictor, etc.			X					
Pressure Control Valves								
Relief, throttling, unloading, sequencing, pressure reducing, etc.			X					
Pressure regulator					X			
Actuation								
Method								
Direct-acting			X					
Pilot-acting						X		
Means								
Manual, mechanical			X					
Solenoid				X				
Electric motor								X
Hydraulic						X		
Pneumatic								X

INVENTORY OF SYSTEMS AND

COMPONENTS OF PRODUCTION MACHINERY

Hydraulic Systems - Continued

MACHINERY SYSTEMS AND COMPONENTS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	< 5
Gages (Including Lube System)								
Pressure			X					
Volume								X
Temperature						X		
Liquid Level			X					
Other							X	
Seals and Packing (Including Mechanical, Pneumatic & Lubrication)								
Gasket		X						
Piston ring					X			
O-ring			X					
U, V, W, packing						X		
Cupped packing							X	
Flanged packing							X	
Felted fibers							X	
Wiper					X			
Metallic ring					X			
Bellows boot								X
Other, unknown		X						
Miscellany								
Reservoir			X					
Oil Cooler							X	
Filter			X					

INVENTORY OF SYSTEMS AND COMPONENTS OF PRODUCTION MACHINERY

MACHINERY SYSTEMS AND COMPONENTS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	< 5
ELECTRICAL AND ELECTRONIC SYSTEMS								
Input (Source) Voltage								
24 DC								X
36 DC								X
Other & unknown DC								X
110 AC				X				
220 AC			X					
440 AC				X				
Other & unknown AC			X					
System Voltage								
24 DC							X	
36 DC								X
Other & unknown DC					X			
110 AC			X					
220 AC			X					
440 AC					X			
Other & Unknown AC			X					
Sliding Contacts (Non-Motor, Non-Generator)								
Commutators								X
Slip rings								X
Brushes							X	
Meters								
Voltage							X	
Current							X	
Power (watts)								X
Energy (watt-hrs)								X
Frequency								X
Other							X	
Switches								
Actuating means								
Manual	X							
Proximity								X

INVENTORY OF SYSTEMS AND COMPONENTS OF PRODUCTION MACHINERY

Electrical and
Electronic Systems - Continued

MACHINERY SYSTEMS AND COMPONENTS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	< 5
Switches (Continued)								
Actuating means (continued)								
Thermal					X			
Limit stop			X					
Pressure						X		
Centrifugal								X
Timer				X				
Photoelectric							X	
Other, unknown							X	
Switches								
Type of action								
Pushbutton		X						
Toggle			X					
Knife blade								X
Rotary selector		X						
Stepping								X
Sampling								X
Others, unknown				X				
Relays								
General purpose			X					
Time delay						X		
Latching								X
Other, unknown						X		
Motors, Brakes and Clutches								
DC motors								X
AC motors	X							
Brakes							X	
Clutches							X	
Miscellany								
Solenoids			X					
Lights			X					
Magnets				X				
Heaters				X				

INVENTORY OF SYSTEMS AND

COMPONENTS OF PRODUCTION MACHINERY

Electrical and
Electronic Systems - Continued

MACHINERY SYSTEMS AND COMPONENTS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	< 5
Miscellany (Continued)								
Electrolytic process								X
Electrostatic plates								X
Welding electrode								X
Cathode ray tube								X
Motor-generator set								X
Inverter								X
Motor starter		X						
Speed controller						X		
Rectifier						X		
Transformer-power			X					
Transformer-signal							X	
Potentiometer							X	
Rheostat					X			
Inductive reactor								X
Capacitive reactor						X		
Voltage regulator								X
Current regulator								X
Vacuum tubes							X	
Transistors							X	
Servo								X

INVENTORY OF SYSTEMS AND COMPONENTS OF PRODUCTION MACHINERY

MACHINERY SYSTEMS AND COMPONENTS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	< 5
PNEUMATIC SYSTEMS								
Power Source and Accessories								
External air supply			X					
Integral compressor						X		
Cooler								X
Dryer								X
Receiver							X	
Filter				X				
Air lubricator					X			
Muffler						X		
Conductors								
Hose					X			
Pipe						X		
Tubing						X		
Manifold							X	
Output Devices								
Motors								X
Rotary actuators								X
Intensifier								X
Cylinders								
Single-acting							X	
Double-acting							X	
Telescoping								X
Other, unknown type								X
Directional Flow Control Valves								
On-off only								
Check						X		
Gate, glove, ball, poppet, etc.						X		
Network switching (2 way, 3 way, 4 way)						X		
Volume Flow Control Valves								
Needle, restrictor, etc.					X			

INVENTORY OF SYSTEMS AND COMPONENTS OF PRODUCTION MACHINERY

Pneumatic Systems - Continued

MACHINERY SYSTEMS AND COMPONENTS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	< 5
Pressure Control Valves								
Relief, throttling, unloading, sequencing, pressure reducing, etc.							X	
Pressure regulator					X			
Actuation								
Method								
Direct-acting				X				
Pilot-acting							X	
Means								
Manual, mechanical					X			
Solenoid					X			
Electric motor								X
Hydraulic								X
Pneumatic							X	
Gauges								
Pressure				X				
Temperature								X
Other								X

INVENTORY OF SYSTEMS AND COMPONENTS OF PRODUCTION MACHINERY

MACHINERY SYSTEMS AND COMPONENTS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	< 5
LUBRICATION SYSTEM								
Lubricants Used								
Greases		X						
Machine oils	X							
Graphite								X
Other								X
Unknown type								X
Type of System								
Manual	X							
Automatic			X					
Splash					X			
Central system					X			
Constant flow						X		
Intermittent flow							X	
Metered flow						X		
Pump								
Motorized				X				
Hand operated								X
Lubrication Device								
Reservoir, tank			X					
Oilers			X					
Pressure cups			X					
Wicks							X	
Spray nozzles							X	
CUTTING FLUID SYSTEM								
Fluid Used								
Oil base							X	
Water soluble base								X
Water								X
Gas, air								X
Other, unknown								X

INVENTORY OF SYSTEMS AND COMPONENTS OF PRODUCTION MACHINERY

MACHINERY SYSTEMS AND COMPONENTS	Percentage Frequency of Occurence							
	> 75	50-75	25-50	20-25	15-20	10-15	5-10	< 5
COOLANT SYSTEM								
Fluid Used								
Oil base						X		
Water soluble								X
Synthetic fluids								X
Water						X		
Gas, air						X		
Other, unknown							X	

APPENDIX E

APPRENTICESHIP TRAINING - SAMPLE WORK SCHEDULES

APPRENTICESHIP TRAINING

Sample Work Schedules

MAINTENANCE MACHINEST (MECHANICAL REPAIRMAN)

Sample Schedule 1

Activity	Approx. Hours of Instruction & Experience
Tool Crib	250
Drill Press	500
Planer & Shaper	500
Gear Cutting and Grinding	500
Milling	1000
Lathe	1000
Bench Work	500
Maintenance of machines	3750
TOTAL	8000

Sample Schedule 2

Activity	Approx. Hours of Instruction & Experience
Tool Crib	500
Drills	500
Lathe - Engine	2000
Milling Machine	1000
Shaper	500
Grinding	500
Bench Work	1000
General Machinery Repair	2000
TOTAL	8000

Sample Schedule 3

Activity	Approximate Hours of Instruction & Experience
Tool Crib and Stock Room Work	400
Layout Helper, General Work	1000
Drill Presses	800
Milling Machines	600
Shaper, Planer, etc.	2000
Engine Lathes	400
Vise and Floor Work	400
Grinding and Sharpening Tools	400
Miscellaneous Machines, including Keyseater	600
Related Instructions	1000
Miscellaneous Related Work	2000
TOTAL	10,000

Source: U.S. Department of Labor, Bureau of Apprenticeship and Training, Selected Apprenticeship Schedules Covering Industrial Plant and Equipment Maintenance Trades, Trade and Industry Publication No. 2, Revised Edition, 1962.

APPRENTICESHIP TRAINING

Sample Work Schedule

HYDRAULIC EQUIPMENT MECHANIC

ACTIVITY	APPROX. HOURS OF INSTRUCTION & EXPERIENCE
Bench Reconditioning	1000
Hydraulic Pipe Fitting	1000
Construction of Hydraulically Operated and Controlled Machines	1000
Maintenance, Repair of Hydraulically Operated and Controlled Machines	4500
Maintenance, Repair of Hydraulic Transmissions and Press Cluthes	500
Total	8000

Source: U.S. Department of Labor, Bureau of Apprenticeship and Training, Selected Apprenticeship Schedules Covering Industrial Plant and Equipment Maintenance Trades, Trade and Industry Publication No. 2, Revised Edition, 1962

APPRENTICESHIP TRAINING

Sample Work Schedules

MAINTENANCE ELECTRICIAN

Sample Schedule 1

Activity		Apprx. Hrs. of Instruction & Experience
Electrical Construction		2076
General Maintenance		1766
Cranes & Elevators		520
Electrical Repair		1650
Power Houses: Substation Construction		850
Maintenance of Power-House and Substations		466
Related Instruction		672
	TOTAL	8000

Sample Schedule 2

Commercial & Industrial Wiring		
Signal Wiring		
Power Wiring		1856
Control Equipment		
Lighting Circuits		
Wire Splicing		
Fixture Work		
Assembly		
Wiring and Repair		
Hanging		
Check & Repair Equipment		
Rigid Conduit Installation		
Motor troubles, detection and repair		1856
Transformers		
Repair Compensators		
Safety Methods		
Install light and power equipment		
Signal Equipment		
Replace fuses, bulbs		1856
Maintain electrical circuits and equipment		
Appliance repair		
Safety Methods		
Motor Repair		
Welding brazing & burning		
General Maintenance		
Safety Methods		1856
First Aid		
Electronic Controls and Circuits		
Induction Heating		
Related Technical Instructions		576
	TOTAL	8000

MAINTENANCE ELECTRICIAN
(Continued)

Sample Schedule 3

Activity	Apprx. Hrs. of Instruction & Experience
Oil & Grease, Motors	1000
House Wiring (company property)	600
Help Shoot Trouble with Experienced Electrician	1400
Disconnect Motors and Electrical Equipment	400
Helping Electrical Installation	1200
Running New Lines	1000
Installing Switches	400
Testing & Analyzing Equipment	1400
Elevators	200
Telephones & Communications System	400
TOTAL	8000

Source: U.S. Department of Labor, Bureau of Apprenticeship and Training, Selected Apprenticeship Schedules Covering Industrial Plant and Equipment Maintenance Trades, Trade and Industry Publication No. 2, Revised Edition, 1962.

APPRENTICESHIP TRAINING

Sample Work Schedules

INDUSTRIAL ELECTRONIC TECHNICIAN

Sample Schedule 1

Activity	Apprx. Hrs. of Instruction & Experience
Electronics	3000
Electrical Control	3000
Motors and Generators	800
Transformers	400
Electrical Instruments - hook up and use	700
Miscellaneous	100
TOTAL	8000

Sample Schedule 2

Mechanical Assembler	500
Wireman Assembler	1000
Cable Designer	500
Chassis Layout	1000
Hot Test Technician	1000
Tuning and Alignment Technician	1000
Technician Repairman Helper	3000
TOTAL	7000

Source: U.S. Department of Labor, Bureau of Apprenticeship and Training, Selected Apprenticeship Schedules Covering Industrial Plant and Equipment Maintenance Trades, Trade and Industry Publication No. 2, Revised Edition, 1962.

APPRENTICESHIP TRAINING

Sample Work Schedules

INSTRUMENT REPAIRMAN

Sample Schedule 1

Activity		Apprx. Hrs. of Instruction & Experience
Tool Crib		200
Power Tools		300
Installation		1400
Test Instruments		500
Air Velocity Instruments		200
Gauges		200
Electronic Equipment		600
Flow Measuring Devices		500
Liquid Level Measuring Devices		400
Time Clocks		200
Temperature Indicators, Recorders, and Controllers		1400
Valves		400
Electronic and Pneumatic Systems		1400
Miscellaneous		300
	TOTAL	8000

Sample Schedule 2

Records and Stock		200
Pressure Gauges and Regulators		600
Pressure Controls, Draft Gauges		800
Thermocouples, Ravotubes, etc.		800
Flowmeters		1000
Temperature Controls		2000
General Instrument Repair		1500
Test Equipment		500
Related Instruction		600
	TOTAL	8000

Sample Schedule 3

Records & Stocks		100 to 200
Test Equipment		300 to 400
Field Installation		300 to 500
General Instrument Repair		3900 to 4200
Trouble Shooting		3000 to 3500
Leadership Training		250 to 300
	TOTAL	7850 to 9100

Source: U.S. Department of Labor, Bureau of Apprenticeship and Training, Selected Apprenticeship Schedules Covering Industrial Plant and Equipment Maintenance Trades, Trade and Industry Publication No. 2, Revised Edition, 1962.

APPRENTICESHIP TRAINING

Sample Work Schedules

MAINTENANCE PIPE FITTER

Sample Schedule 1

Activity	Apprx. Hrs. of Instruction & Experience
Shop Work - Hand threading, operation of threading machines, grind chasers, drilling and tapping holes, cut gaskets	1200
Rigging - Erect Scaffolds, supports, etc.	200
Flanged piping - Break and make joints, clean, renew gaskets	600
Valves - Repack, repack under pressure, install globe, gate and reducing valves, strainers, shower controls and heating system controls	1200
Piping - Bend steel, brass, copper and alloy pipe. Measure, cut, caulk and install cast iron pipe	500
Pipe Hangers - Make and install hangers	500
Layout - Measure, plumb, level and square. Job planning and listing of material required. Make and read drawings	700
Pipe Covering - All types of insulation	800
Plumbing - Install and repair sanitary equipment. Wipe lead joints	500
Repair Steam, Water - Spot Trouble - Determine Equipment Air or Process Pipe needed, method of repair	1300
New Line - Make layout - Locate valves for shut-off and drainage	500
TOTAL	8000

Sample Schedule 2

Fundamental Pipe Fitting Practice	960
Service Installation - Drainage and Ventilation	600
Fixture Installation	600
Piping for Steam	1600
Sprinkler System Installation	960
Maintenance and Repair	2000
Piping for H.P. Gas and Steam Lines	1040
Clerical Training	240
TOTAL	8000

Source: U.S. Department of Labor, Bureau of Apprenticeship and Training, Selected Apprenticeship Schedules Covering Industrial Plant and Equipment Maintenance Trades, Trade and Industry Publication No. 2, Revised Edition, 1962.

APPRENTICESHIP TRAINING

Sample Work Schedules

MILLWRIGHT

Sample Schedule 1

Activity	Apprx. Hrs. of Instruction & Experience
Safety in Operations	400
Machinery Erectors	3000
Millwright General Repairs	2500
Welding	500
Miscellaneous	600
TOTAL	7000

Sample Schedule 2

Moving, placing, setting, aligning and assembling of all machinery and equipment	1000
Making all connections direct to machines and equipment	1000
Fabrication and erection of guards, attachments and accessories for machines of any description	1000
Fabrication of machines and equipment made of metal or metal substitutes on a construction job	1000
Setting and removing foundation beams or timbers	1000
Electric and Acetylene Welding	1000
Rough carpenter work in connection with maintenance and installation of machinery	1000
Repair and maintenance of all machinery, equipment and other items pertinent to the proper operation of a construction job	1000
TOTAL	8000

Sample Schedule 3

Introductory Training	300
Drill Press	300
Shaper	300
Engine Lath	300
Milling Machine	300
Bench and Floor	400
Rigging and Climbing	500
Installation	1500
General Maintenance and Repair	3000
TOTAL	6900

Source: U.S. Department of Labor, Bureau of Apprenticeship and Training, Selected Apprenticeship Schedules Covering Industrial Plant and Equipment Maintenance Trades, Trade and Industry Publication No. 2, Revised Edition, 1962.

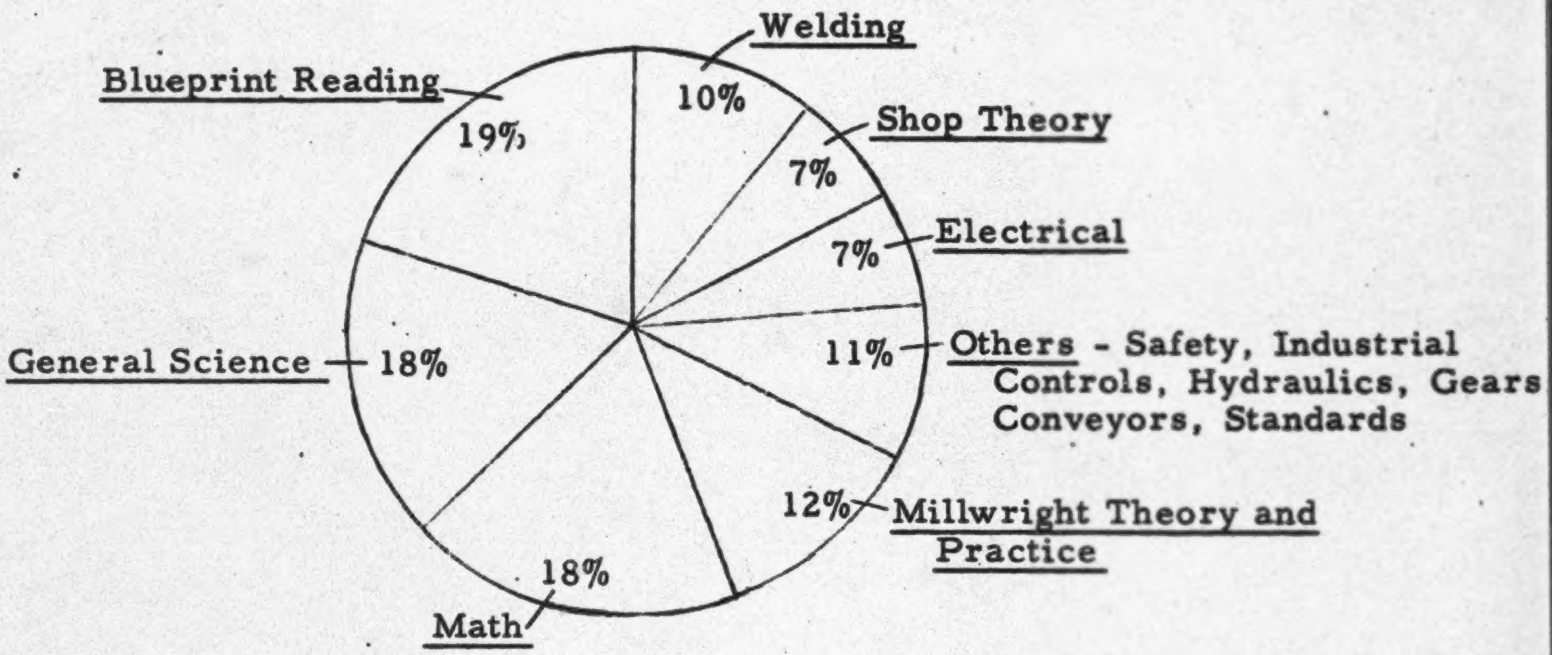
APPENDIX F

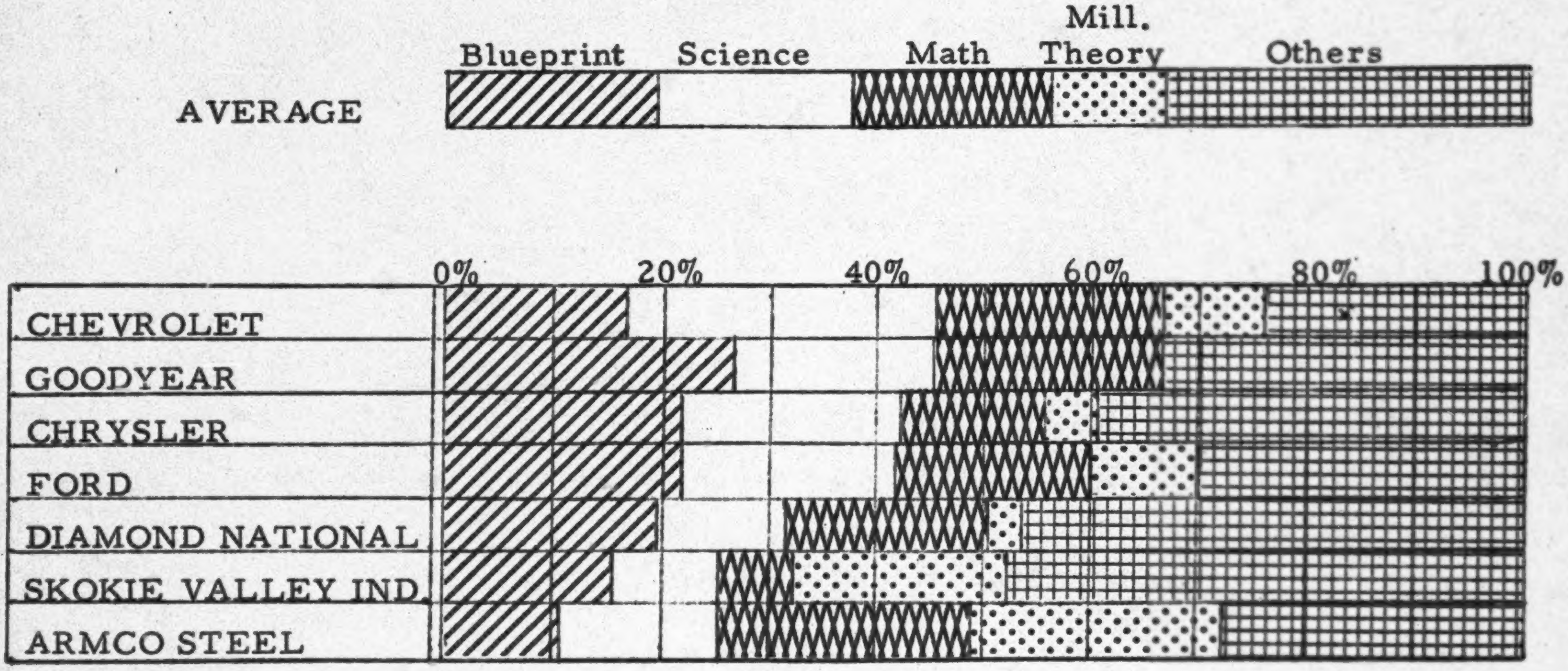
ALLOCATION OF SUBJECT TIME IN VARIOUS MAINTENANCE TRAINING PROGRAMS

MILLWRIGHT

Related Classroom Instruction

Average Percentage Time Spent by Subject in Firms Studied [#]



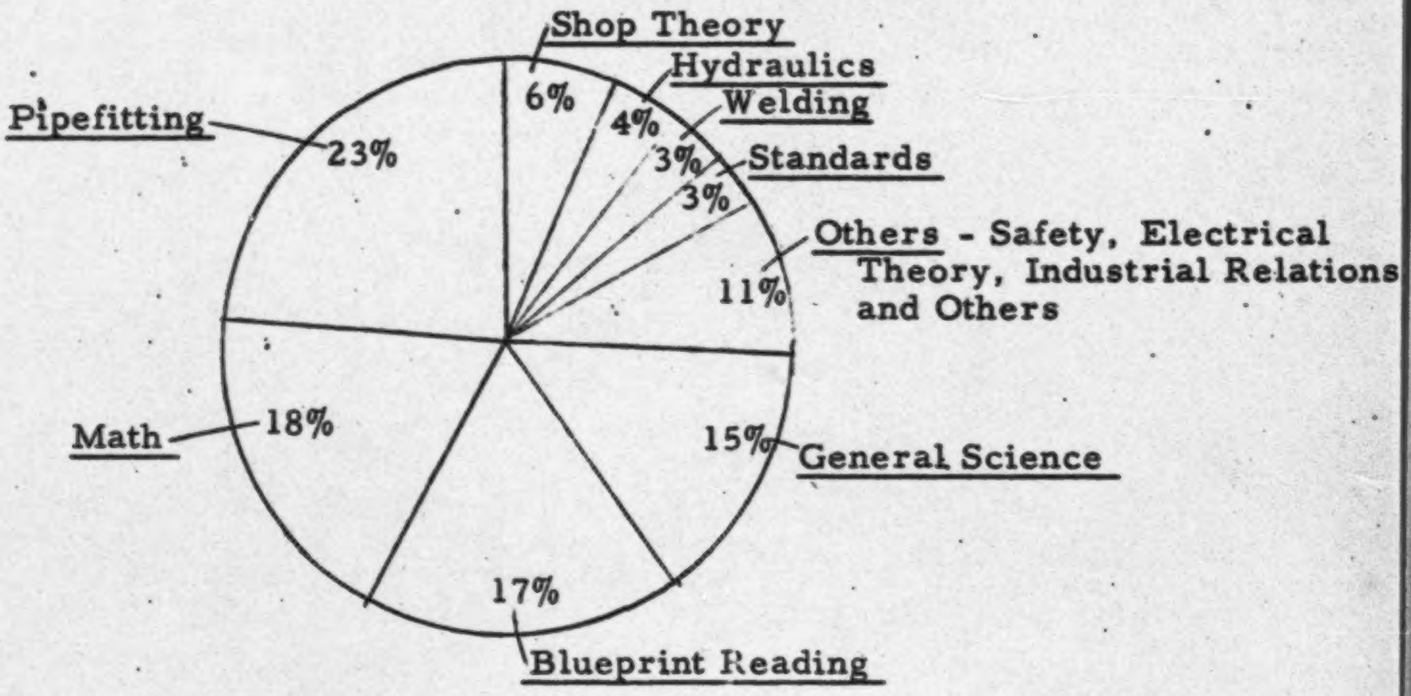


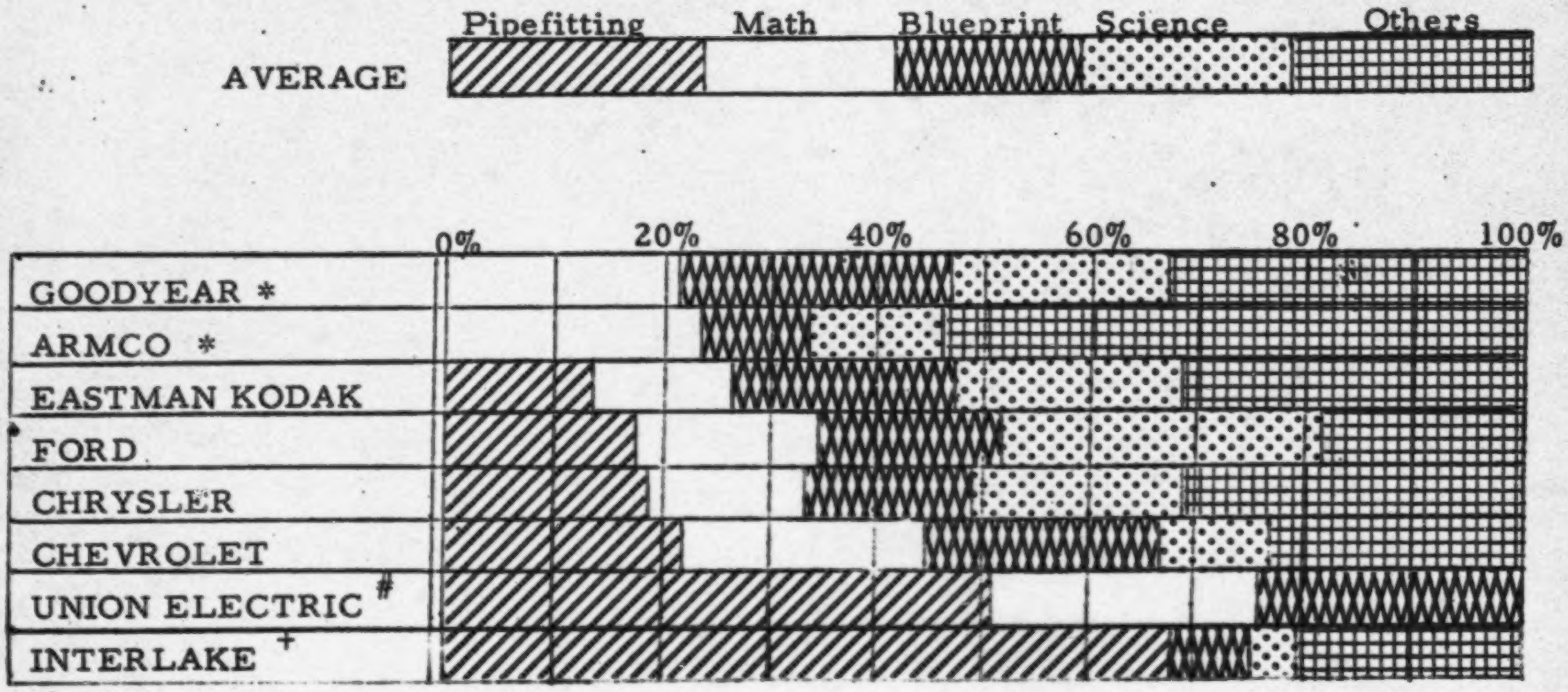
[#] Due to rounding, the percentage figures do not total 100 percent.

PLUMBER-PIPEFITTER

Related Classroom Instruction

Average Percentage Time Spent by Subject in Firms Studied





* NOTE: No Pipefitting (Plumbing)

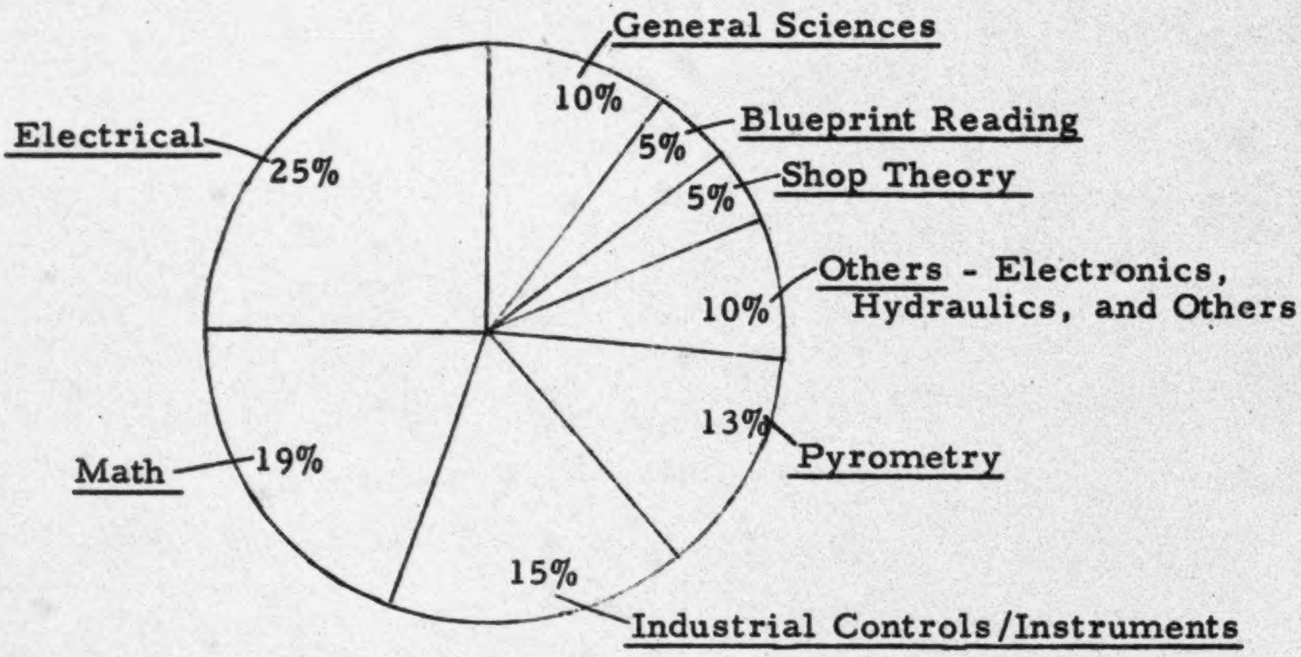
# NOTE: No General Sciences

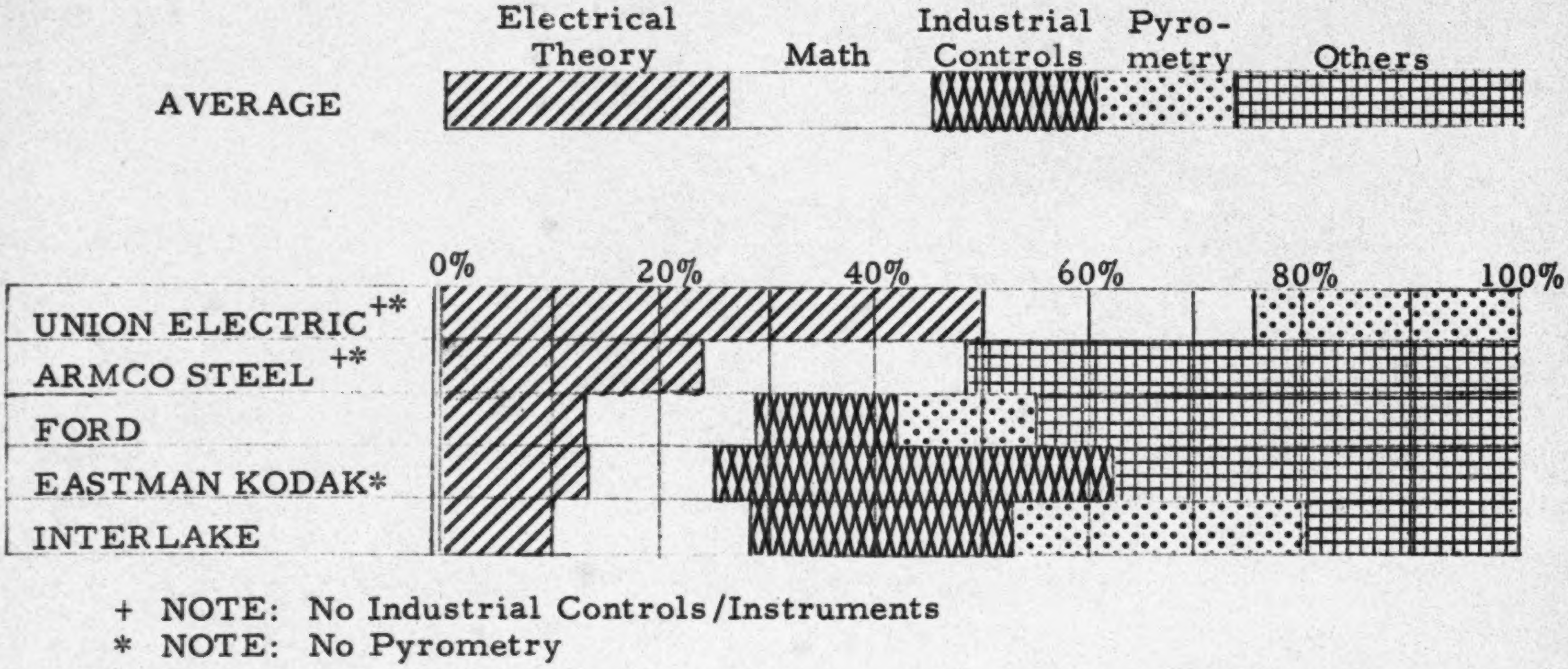
+ NOTE: No Math

INSTRUMENT REPAIRMAN

Related Classroom Instruction

Average Percentage Time Spent by Subject in Firms Studied





+ NOTE: No Industrial Controls/Instruments
* NOTE: No Pyrometry

# Due to rounding, the percentage figures do not total 100 percent.

APPENDIX G

THE CLEARINGHOUSE PROPOSAL

PROPOSED
CLEARINGHOUSE FOR INDUSTRIAL TRAINING MATERIALS

During the last year, the Midwest Institute for Research and Training has been conducting a research study into the training and skill requirements of industrial machinery maintenance workers. Since every manufacturing company in every industry has maintenance personnel, we have been exposed to a wide scope of training activities--in industry, in the educational system, and in training organizations. Out of this exposure has come the concept of the Clearinghouse for Industrial Training Materials which we feel will become an important factor in resolving industry's growing requirements for trained workers.

Our investigation of the training and skill requirements of machinery maintenance workers evoked a common response from industrial training directors and from individuals involved in vocational and adult training...

> ...the primary reason for the lack of training programs in this field is the unavailability of training manuals, textbooks, and other training aids that are essential to the effective training of maintenance workers.

Accompanying this comment was the acknowledgement that trained maintenance workers are a critical problem in industry today and this problem will become even more critical in the future.

Our investigations confirmed the fact that published and readily available maintenance training materials are almost non-existent. However, as we investigated the individual training efforts of industry, we found that a number of companies not only had instituted extensive maintenance training programs for their own use, but had also developed training manuals, textbooks, and training aids for these programs. We found these maintenance training materials in all forms--formal text materials developed by Ford Motor Company for their apprenticeship programs, programmed instruction materials developed by duPont for their own use, elaborate training films and manuals the airlines use in their aircraft maintenance training, and manuals, slides, models, and films supplied by machinery component manufacturers such as General Electric Company, Racine Hydraulics & Machinery Company, and Gulf Oil Company. Although these training materials are oriented to the specific needs and interests of the company that developed them, in many cases they are sufficiently generic to be used directly in other maintenance training programs; other materials can be readily adapted to general maintenance training programs with a minimum of editing and rework.

These training materials have not attained the degree of interchange that might be expected in industry for several reasons. Primarily, most of these companies feel that they are not in the business of providing training materials to others and, as a result, have not made an effort to reproduce these materials and make them available to others. In addition, there is normally some communication on training materials among companies in the same industry, but surprisingly little direct exchange of training information from one industry to another. More often than not, we found training directors unaware of materials produced by other companies that would be directly useful in their training activities.

We estimated that industry has an investment of $10-$15 million in maintenance training materials that could be directly and quickly applied to training maintenance personnel. The catalyst required to accomplish this transfer of a specific company's investments in training materials to the overall problem of training workers for industry's needs is an organization that would act as a focal point for acquiring, evaluating, and distributing these industrial training materials. The Midwest Institute for Research and Training proposes to establish and operate a not-for-profit organization that would act as a clearinghouse for these industrial training materials. The Clearinghouse would...

...contact private companies and other organizations that have developed maintenance training materials for their own use and attempt to convince them to make these materials available to all of industry and to vocational education and training groups.

...examine these materials and determine the extent to which they either fit general industry's needs or can be readily adapted to meet these needs.

...arrange to have these materials reproduced so that they can be used by organizations interested in establishing maintenance training programs and disseminate these materials to private companies, apprenticeship programs, adult & vocational training courses, and others, for a fee that would permit the Clearinghouse to sustain its operations.

...identify areas in which additional training materials are needed and encourage the development of these materials.

...determine the extent to which these materials can be used in other training fields such as automotive repairmen, aviation mechanics, and other occupations which require some technical knowledge and training.

We feel that this Clearinghouse for Industrial Training Materials would provide a major contribution toward harnessing the resources and capabilities of industry to resolve the problem of supplying adequately-trained maintenance workers. A number of large companies have

already expressed an interest in participating in this venture, both as contributors of their training materials and as users of other training materials that would be made available to them through the Clearinghouse. As a result, we feel that the Clearinghouse for Industrial Training Materials can and will accomplish its objective. Furthermore, we feel that this clearinghouse concept is applicable in other areas of industrial training and would eventually hope to extend this organization's activities into these other fields.

APPENDIX H

CORE MAINTENANCE TRAINING SUBJECTS

CORE CURRICULUM FOR A BASIC MAINTENANCE TRAINING PROGRAM

Blue Print Reading

- Mechanical schematics
- Electrical schematics, simple
- Hydraulic schematics, simple
- Mechanical, electrical & hydraulic symbols
- Read scale drawing
- Make freehand sketches

Mathematics and Measurement

- Arithmetic (add, subtract, multiply & divide)
- Fractions
- Ratios, proportions & taper/foot
- Calculate rpm; peripheral speed

Mechanics

- Basic principles, levers
- Basic principles, pulleys & gears
- Basic principles, inclined planes
- Basic principles, cams & other mechanisms
- Measurement, rule or scale
- Measurement, vernier caliper
- Measurement, protractor
- Measurement, micrometer
- Measurement, dial indicator
- Components, belts, pulleys & chains
- Components, couplings & drive shafts
- Components, ball & roller bearings
- Components, sleeve (journal) bearings
- Components, gears, spur
- Components, gears, bevel, worm, etc.

Mechanics (Continued)

- Components, clutches & brakes
- Components, cams & followers
- Troubleshooting, principles

Hydraulics

- Basic principles, force, pressure & torque
- Basic principles, hydraulic circuitry
- Basic principles, theory of hydraulic flow
- Basic principles, hydraulic fluids

Electrical & Electronics

- Basic principles, AC theory
- Basic principles, DC theory
- Basic principles, circuitry (series, parallel)
- Basic principles, wiring fundamentals
- Basic principles, electronic circuitry
- Measurements, ammeter & voltmeter
- Measurement, wattmeter
- Components, resistors & capacitors
- Components, relays
- Components, motors
- Troubleshooting, principles

Pneumatics

- Basic principles, circuit theory
- Basic principles, pressure & force
- Components, cylinders
- Components, valves (manual)
- Components, lubricators & filters
- Components, regulators & pressure gages
- Troubleshooting, principles

Miscellaneous

- Lubrication, theory & principles
- Lubrication, lubricants (greases, oils, etc.)
- Safety, mechanical
- Safety, electrical
- Safety, hydraulic
- Safety, pneumatic